MARKET 37X — RESIDENTIAL HVAC INSTALLATION AND MAINTENANCE PRACTICES

Market Scope

This cross-cutting market deals with installation and maintenance practices related to Wisconsin residential furnaces and central air conditioners. It includes achievable potential from installation practices for new installations and improvements to the efficiency of existing systems. This market does not include purchase choices for new equipment: that aspect of the market is covered under Markets 19 and 20.

Market Characteristics

More than three quarters of Wisconsin homes are heated with a forced air furnace and we estimate that nearly two-thirds of homes will have central air conditioning as of 2006, constituting about a million units in the state. Moreover, between 75,000 and 100,000 new installations of each occur in Wisconsin each year; these are made up of replacements for existing systems, additions to homes that do not have central air conditioning, and units installed in new homes.

Field research has shown that the installed performance of these systems is often below their rated performance due to sub-optimal installation and maintenance practices. In particular, the optimal performance of central air conditioners is dependent on proper refrigerant charge and airflow (often abbreviated as RCA). Field data from other states (and limited Wisconsin data) suggest that more than half of central air conditioners have RCA outside manufacturers' specifications. Correcting RCA problems (and cleaning outdoor condenser coils that frequently become fouled) has been shown to yield a 10 to 20 percent efficiency gain.

Furnaces are less sensitive than air conditioners to installation defects, but many furnaces are installed in homes with existing air conditioners: installation of a new furnace thus presents an opportunity to correct air conditioner performance problems concurrently. In addition, multi-stage variable speed furnaces have captured about a fifth of the furnace market; electricity consumption by these units is sensitive to filter airflow resistance, creating an opportunity for electricity savings from low-resistance filters.

Lack of awareness on the part of homeowners regarding the prevalence of sub-performing systems—as well as the relatively minor impact on energy bills from correcting these defects—may limit the potential for this market, especially among the large population of homes with existing systems, where an if-it-ain't-broke-don't-fix-it attitude may prevail.

Programs in California have achieved success in dealing with central air conditioning RCA issues by providing telephone and computer support for field technicians. One of these programs—CheckMe®, developed by Proctor Engineering—has been cited as an exemplary program design by the American Council for an Energy Efficient Economy. In Wisconsin, Focus on Energy has initiated efforts to promote these practices in a slightly different manner, by providing paper worksheets for technicians to diagnose and correct RCA problems. Regardless of the specific approach, third-party verification of sampled units is important.

Programs to promote air conditioner installation practices may receive a boost in 2007, when the EPA is considering separating the rated efficiency and the installation quality in its ENERGY STAR qualification criteria. Under this approach, units would receive a separate ENERGY STAR label for installation.

Sizing of systems can also affect performance. Although research has shown that Wisconsin furnaces average about twice the capacity needed to meet the home's heating load on a cold winter day, furnace efficiency is not thought to be strongly affected by over-sizing—especially for Wisconsin's large population of sealed-combustion, high efficiency furnaces.

Air conditioner efficiency does suffer when units are over-sized, because air conditioner performance is poor in the first few minutes of operation. The more the unit is over-sized, the shorter its cycles will be on average, and the more the first few minutes of operation will factor into the overall run-time of the unit. While research in hot climates has shown that many units are egregiously over-sized, the more limited data from Wisconsin are less clear on this issue. Moreover, contractors are loathe to risk undersizing a unit and therefore resistant to attempts to change sizing practices.

Program Approaches

We focus here on a programmatic effort to improve RCA for new and existing central air conditioners in Wisconsin, by providing incentives to contractors and consumers for proper RCA tuning.

PROGRAM AREA 37X.01 — INCENTIVES FOR CENTRAL AIR CONDITIONER TUNING.

This program would provide incentives to consumers and contractors to stimulate an increase in the number of new and existing air conditioners where refrigerant charge and airflow are tested and corrected to manufacturers' specifications. The model used here to estimate achievable potential has assumptions about the savings that would typically derive from these tune-ups, as well as a projection of the scale of program participation. The model looks separately at savings and participation for new and existing systems.

Table 1, Midpoint estimates of program costs and achievable impacts for program area 37x.01 — Incentives for central air conditioner tuning.

		Incremental First-Year Impacts		
Year	**Program Costs** ($000s)	Peak kW	Annual kWh (000s)	Annual therms (000s)
1	$383	356	139	0
2	$633	731	284	0
3	$1,125	1,464	568	0
4	$2,032	2,802	1,086	0
5	$3,506	4,956	1,917	0
6	$5,479	7,805	3,013	0
7	$7,528	10,718	4,130	0
8	$9,165	12,992	4,997	0
9	$10,221	14,397	5,528	0
10	$10,810	15,121	5,796	0

(TECHNICAL DOCUMENTATION)

Program Area 37x.01 — Incentives for central air conditioner tuning

Model inputs are shown below, and described in more detail on the following pages.

Model Inputs (37.01)			Value	±
1		**Per-Unit Impacts (unit = one central air conditioner)**		
	a	avg. nominal SEER (new system)	13.5	0.5
	b	avg. nominal SEER (Year 1, older system)	9.5	0.5
	c	SEER field performance factor	1.0	0.15
	d	annual increase in avg. SEER of existing units	0.1	0.05
	e	annual increase in avg. SEER of new units	0.05	0.025
	f	efficiency derating factor for installation defects (existing)	0.85	0.05
	g	efficiency derating factor for installation defects (new)	0.90	0.075
	h	Mean cooling capacity of unit (tons)	2.5	0.25
	i	Mean annual hours of operation	400	100
	j	estimated SEER - EER difference	1.5	0.25
	k	Diversified demand factor	0.75	0.10
2		**Program Participation**		
	a	maximum annual number of new systems	50,000	15,000
	b	maximum annual number of existing systems	40,000	30,000
	c	logistic parameter *a*	100	50
	d	logistic parameter b	0.75	0.40
	e	program net-to-gross ratio	0.75	0.50
3		**Program costs**		
	a	Fixed program costs	$200,000	$100,000
	b	Variable costs per-participant (incentive, and admin.)	$125	$50
4		**Measure life (years)**		
	a	Measure life (new systems)	15	5
	b	Measure life (existing systems)	10	5

1. Per Unit Impacts

We first assume that a typical new central AC system will have a nominal SEER rating of 13 ***(Input 1a)***, and that the average older system will have a nominal SEER rating of 9.5 ± 0.5 ***(Input 1b)***. The latter is based on data collected from the Center's 1999 Energy and Housing study (Pigg and Nevius, 2000), and increased slightly for the seven years that have elapsed since the study was conducted. We further introduce a "SEER field performance" factor of 1.0 ± 0.15 to account for uncertainty related to how well the federal test procedure that measures SEER reflects seasonal performance for Wisconsin systems

(Input 1c). This factor essentially allows for the actual field SEER to differ by up to two SEER points on either side of the mid-point estimate (e.g. SEER 11 or SEER 15 instead of SEER 13). Finally, we also postulate an increase over time in the average rated SEER for existing systems of 0.1 ± 0.05 per year ***(Iinput 1d)***, and an increase of 0.05 ± 0.025 for new systems ***(Input 1e)***.

We next estimate the average amount by which RCA (and condenser fouling) defects reduce the rated performance of the system, which we model as a de-rating factor on the nominal SEER. Based on Mowris et al., 2004, we assume a range of 0.85 ± 0.05 for this factor, implying between 10 and 20 percent savings from correcting RCA problems with existing air conditioners ***(Input 1f)***.

We used a slightly higher (but more uncertain) factor of 0.90 ± 0.075 for new air conditioners ***(Input 1g)***. This has to do with an assumption that many new systems will be equipped with thermostatic expansion valves (TXVs) after the new SEER-13 standard comes into play in 2006. Bench-testing of systems with and without TXVs under different charging conditions suggests that systems with TXVs are less susceptible to performance degradation from improper RCA (Farzad and O'Neal, 1993). On the other hand, Mowris (2004) found that in California, systems with TXVs had as much performance improvement as non-TXV systems. However, these improvements may not fully translate to Wisconsin, since the Mowris study found that the poorer-than-expected performance of TXV systems had to do with failure to properly mount and insulate the refrigerant line sensing bulb in systems installed in hot attics, which are uncommon in Wisconsin.

We also duplicate here assumptions from Market 20 about average system size, operating hours, difference between SEER and EER and diversified demand ***(Inputs 1h through 1k)***. These are documented under Market 20.

Together, these inputs work out to the midpoint estimates of energy and peak demand savings shown below.

TABLE 2, MIDPOINT ESTIMATES OF YEAR 1 PER-UNIT ENERGY AND DEMAND SAVINGS FROM CORRECTING REFRIGERANT CHARGE AND AIRFLOW PROBLEMS WITH CENTRAL AIR CONDITIONERS.

	Annual kWh savings	Peak kW savings
New system	103	0.217
Existing system	223	0.312

2. Program Participation

Potential program participants can be divided into those who install a new central air conditioner in a given year (this may be a replacement system, addition of central air to an existing home that lacked central AC, or construction of a new home), and those who have an existing central air conditioner that could be tuned up.

Survey data from the Center's 2003 Appliance Sales Tracking Survey (Bensch and Weitner, 2004) suggest that about 60,000 ± 11,000 Wisconsin single-family households in older homes purchase a new central air conditioner in a given year.[1] Moreover, about 25,000 new homes are built in Wisconsin each year, the vast majority of which have central air conditioning. Together, these statistics suggest that about 85,000 new air conditioners are installed in Wisconsin single-family homes annually.

We estimate that a long-running, mature program promoting installation practices could ultimately affect perhaps 50 to 75 percent of systems installed in older homes and 25 to 50 percent of systems installed in new homes. We therefore take 50,000 ± 15,000 as an estimate of the maximum annual participation from new air conditioner installations ***(Input 2a)***.

For existing air conditioners, the Center's 1999 Energy and Housing study found that about half of older single-family homes had central air conditioning. Survey data from the Center's 2003 Appliance Sales Tracking Survey further suggest that about 2.5 percent of households add central air conditioning each year, implying a statewide 2006 saturation of about 67 percent. This works out to roughly one million central systems in existing Wisconsin homes in 2006.

Data from Center's 2003 Appliance Sales Tracking Survey suggest that about 40 percent of furnace purchases are not associated with a simultaneous AC purchase. However, the proportion of these households that have central AC is unknown. On the conservative side, one could assume that nearly all central AC systems are replaced at the same time as the furnace. On the more optimistic side, one could assume that central AC saturation among furnace replacers is about the same as the general population. These two extremes suggest somewhere between zero and 12,000 furnace installations per year in homes with existing central AC systems.[2] Tracking data from the Energy Center's Furnace and AC Tracking System indicate that about half of furnace sales occur during the first and fourth quarters of the year, when assessing AC refrigerant charge is difficult or impossible. This implies somewhere between zero and 6,000 furnace installations per year occur where central AC system RCA improvements could be made concurrently.

This still leaves roughly 970,000 Wisconsin households with existing air conditioners. Many—if not most—of these homeowners will likely have little motivation to address refrigerant charge or airflow if the system is functioning and providing acceptable comfort. On the other hand, a program that offers a clean-and-tune and little or no cost to the homeowner could stimulate a significant response. For the purposes here, we have estimated the maximum annual participation for these households at 2.5 ± 2.0 percent annually, or about 35,000 ± 30,000 households per year. Together, these two estimates add up to a maximum annual potential of somewhere between 10,000 and 70,000 existing central AC systems per year ***(Input 2b)***.

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[1] This is based on a self-reported purchase rate of 4 percent among owners of single-family homes built prior to 2000, and Census data showing about 1.4 million such households in the state.

[2] The latter figure is calculated as 1.4 million households * 3.4% furnace replacement rate * 40% of furnace replacements not associated with central AC replacement * 67% central AC saturation among single-family homes.

This potential could not be immediately achieved, since the program would need to gradually pull contractors and consumers within its orbit. We assume an S-shaped logistic growth function toward both of these maxima, of the form

$$P(t) = L/(1+ae^{-bt})$$

Where

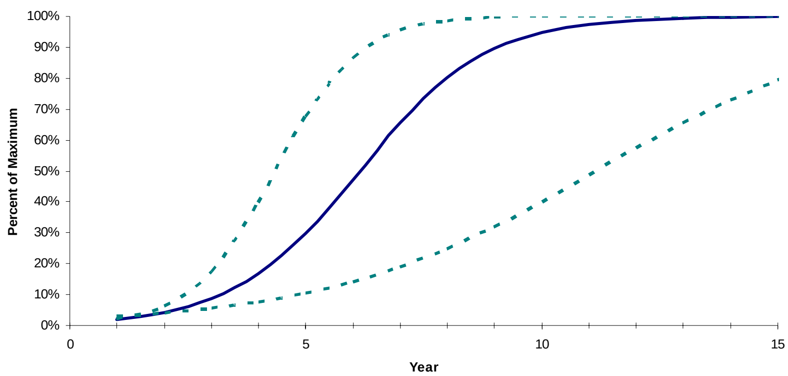
P(t) = annual participants in Year *t;*

L = estimated maximum number of participants per year; and,

a, b are parameters that help determine the shape of the S-curve.

We use 100 ± 50 for the value of *a* ***(Input 2c)***, and 0.75 ± 0.25 for the value of *b* ***(Input 2d)***. These parameter estimates give rise to the (normalized) S-curve of the form shown below, indicating that at the mid-point (solid line) about a third of the maximum annual achievable potential could be realized within five years, and nearly all can be achieved within 10 years. The assigned uncertainties result in a wide range of possible trajectories, however, as indicated by the curves defined by the extremes (dashed lines).

FIGURE 1, ESTIMATED GROWTH IN NORMALIZED PROGRAM PARTICIPATION.



The combined uncertainty in maximum annual participation and the S-curve parameters results in an overall uncertainty in Year 5 participation of between 5,000 and 30,000 households that install new central AC systems, and between 3,000 and 30,000 households with existing air conditioners that participate.[3] (The uncertainty in Year 10 participation is 30,000 to 60,000 and 10,000 to 65,000 participants for the two groups, respectively.)

The mid-point program trajectory is reasonably consistent with reported participation for California's CheckMe! program (York and Kushler, 2003). That statewide program had about

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[3] These are 90 percent confidence intervals.

53,000 participants in 2002, four years after start-up. According to the 2001 Residential Energy Consumption Survey (EIA, 2004), California has about four million central air conditioners, or about four times as many as we estimate for Wisconsin.[4] A comparable program in Wisconsin would thus scale to about 13,000 participants in Year 4, not far different than the 15,000 obtained from our midpoint estimate based on the logistic projection.

Finally, we estimate program net-to-gross ratios to account for the fact that some contractors may already be practicing RCA tuning and some owners of existing systems may already be inclined to have their system tuned up. In terms of contractor practices, recent interviews with 30 participating contractors by Focus on Energy evaluators showed that two-thirds to three-quarters were already practicing some form of RCA testing prior to participation in the program (Talerico, 2004).

For consumer practices in maintaining existing central air conditioners, the Energy Center's 1999 Energy and Housing study asked homeowners about the frequency with which they typically maintained their central air conditioner; nearly 40 percent of respondents reported having their system checked-up at least once a year, about one in four reported having a refrigerant check at least once a year, and about half report checking refrigerant at least every six years.

Taken at face value, the above statistics would imply that the majority of new systems are properly adjusted and the majority of existing systems are regularly maintained and tuned. However, the former study notes that the contractors who were interviewed could be early-adopter contractors, and this proportion could drop under wider program implementation. And socially desirable responding is likely a significant factor in the homeowner self-reports from the Energy Center study. Moreover, the relatively rosy picture of central AC installation and maintenance practices painted by these studies is contradicted by the limited field data available on Wisconsin systems (Deforest, 2005a).

In the face of this uncertainty, we adopt program net-to-gross ratio of 0.75 ± 0.50 for both new and existing systems ***(Input 2e)***. This range accommodates both scenarios where most impacts under the program would have occurred anyway, to a scenario in which the net impacts from the program are actually somewhat greater than that for participants alone. The latter could occur if the program results in increased general adoption of RCA evaluation outside the context of the program.

3. Program Costs

We estimate a fixed program cost of $150,000 ± $100,000 for this program ***(Input 3a)*** for general administrative program support, marketing, verification, and training of contractors. The latter cost would not be substantial: under the current Focus on Energy effort, a training curriculum has already been developed, and the cost of conducting is borne by HVAC distributors.

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[4] Table HC4-7a.

The market cost of performing standard central AC clean and tune has been estimated at about $90, though with additional programmatic reporting requirements, this becomes more on the order of $125 (Deforest, 2005b). The latter figure would be a reasonable estimate of the variable program cost if it is assumed that the program would subsidize the entire cost of the work.

Separate data for the statewide California CheckMe! Program indicates an overall program cost of about $84 per diagnostic run for 2002 (York and Kushler, 2003).

Based on these figures, we estimate the variable cost of the program at $125 ± $50 ***(Input 3b)***.

4. Measure Life

The effective life of savings from correcting refrigerant charge and airflow are somewhat uncertain. In the absence of system refrigerant leaks or changes to the air furnace, the savings should accrue over the remaining life of the unit. (Airflow may drop over time due to coil fouling unrelated to the tune-up, but this would occur regardless of participation in the program). We take 15 ± 5 years as the effective savings life for a new system ***(Input 4a)***, and 10 ± 5 years as the effective savings life for an existing system ***(Input 4b)***.

References

Bensch, Ingo and Sean Weitner. 2004. *Appliance Sales Tracking Study 2003*. Wisconsin Department of Administration. Available from www.ecw.org as Report 232-1.

Deforest, W. (2005a) *Field Operating Characteristics of Central Air Conditioners,* Wisconsin Focus on Energy, January, 2005.

Deforest, W. (2005b) Personal Communication, June 2, 2005.

EIA (2004). 2001 Residential Energy Consumption Survey, Energy Information Agency. See www.eia.doe.gov/emeu/recs/contents.html .

Farzad, M. and O'Neal, D. (1993) *Influence of the Expansion Device on Air Conditioner System Performance Characteristics Under a Range of Charging Conditions,* ASHRAE Transactions, paper 3622, American Society of Heating Refrigerating and Air Conditioning Engineers, Atlanta Georgia.

Mowris, R., Blankenship, A., and Jones, E. (2004) *Field Measurements of Air Conditioners with and without TXVs*, Proceedings of the 2004 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy.

Pigg, S. & Nevius, M. (2000). *Energy and Housing in Wisconsin: A Study of Single-family Owner-Occupied Homes* (Report nos. 199-1 and 199-2). Energy Center of Wisconsin, Madison, WI.

Talerico, T. (2004) *Participating HVAC Contractor Interview Results — Heating and Cooling Initiative*, memo report from Tom Talerico, Glacier Consulting to Oscar Bloch, Wisconsin Department of Administration, May 13, 2004.

York, D. and Kushler, M. (2003) *America's Best: Profiles of America's Leading Energy Efficiency Programs*, American Council for an Energy Efficient Economy, Washington, D.C., Report U032.